

Initially presented as an address at the Symposium on "Animals of New South Wales and their History in the 20th Century" at the 1993 Annual General Meeting of the Royal Zoological Society of New South Wales

## Disappearing frogs

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### ABSTRACT

Public attention was aroused in 1989 to a world-wide phenomena involving the decline of frog species. Since then herpetologists around the world have begun to document the nature and scope of these declines. In Australia, two frog species (*Rheobatrachus silus* and *Taudactylus diurnis*) appear to have become recently extinct, another two may be facing imminent extinction (*Taudactylus eungellensis*, *Taudactylus rheophilus*) while a number of other species (including *Litoria castanea*, *Litoria nyakalensis* and *Rheobatrachus vitellinus*) appear likely to become extinct in the near future. In addition, various frog populations are facing local extinctions within substantial parts of their range. The pattern of frog disappearances in Australia is discussed along with some of the suggested causes for these declines. Actions implemented in Australia and elsewhere to deal with declining frog species are reviewed. Developments in the management of the endangered frog species, the Green and Golden Bell Frog *Litoria aurea* in New South Wales are referred to.

### INTRODUCTION

In recent years there has been on-going debate about endangered species (e.g., Wilson and Peter 1988). The global decline in biodiversity has effected most animal groups. The plight of pandas, whales, white rhinoceroses and jungle cats have been portrayed in the scientific literature and through the public forum as examples of this process. Frogs, although not as well publicized, have also suffered from species reduction and population declines. Declines in frog populations have been reported from all parts of the globe including Australia (Phillips 1990; Ferraro and Burgin 1993a; Ingram and McDonald 1993).

Discussions during the First World Congress of Herpetology, held in the United Kingdom in 1985, centred on perceptions of global changes in frog populations. Field ecologists from a number of countries reported declines in frog numbers and species. Although most participants were scientists working in the northern hemisphere, their southern hemisphere counterparts signalled similar ominous warnings. The congress was the venue whereby the extent of the frog population declines was put into perspective and the beginnings of an assessment and responses formulated. This paper reviews the response, concentrating mainly on Australian species.

In 1990, the first quantitative reports documenting the decline in frog populations appeared (Baringa 1990; Blaustein and Wake 1990; Martin 1990; Phillips 1990). These papers, although preliminary, removed conjecture about the seriousness of the decline. Declines were reported in common as well as uncommon species. For example one of the best known American frogs, the Northern Leopard Frog *Rana pipiens* was common and widespread 20 years ago. It was frequently used for scientific study being a relatively large and easy to keep species. A survey conducted in 1994 of 301 Leopard Frog collecting sites revealed that the species is now only present in 15 of these localities (Pechmann and Wilbur 1994).

Quantitative data have begun to reveal that the decline has truly global dimensions. Reports from South Africa (Baard 1989), Britain (Beebee *et al.* 1990), Central America (Crump *et al.* 1992; Hedges 1993), South America (Heyer *et al.* 1988), Europe, (Sjogren 1991; Semb-Johansson 1992), North America (Corn and Fogleman 1984; Hayes and Jennings 1988; Mossman *et al.* 1992; Wissinger and Whiteman 1992) and Australia (Czechura and Ingram 1990; McDonald 1990; Tyler 1991) have provided the basic information for analysis and determination of patterns of decline.

## THE AUSTRALIAN SCENE

Hero (1991) and Tyler (1991) reviewed the status of Australian frog populations and both confirmed that the demise was occurring at an alarming rate. Cribb (1993), in an address to the Australian and New Zealand Associations for the Advancement of Science (ANZAAS), reported that 29 of the 204 known frog species in Australia were in serious decline. Professional and amateur herpetologists became involved in frog surveys aimed at documenting and monitoring this decline.

The rate of reduction of frog species had to be determined as well as identifying the most vulnerable species. Early studies indicated that frog kinship was not a factor in the decline as frog species from distantly related groups were equally affected. There was no immediate pattern obvious in the types of frogs that were most at risk. This inconsistency is reflected by the extinction of some Australian species. The last reported sighting of the Southern Day Frog *Taudactylus diurnis* was made in 1981 (Czechura and Ingram 1990) while in the same region of southern Queensland, the last sighting of the Gastric Brooding Frog *Rheobatrachus silus* was also made in 1981 (Czechura 1991). Both species are now considered to be extinct.

Frogs with close affinities to the above two species have also suffered. Searches for *Taudactylus eungellensis* and *Rheobatrachus vitellinus* have failed to locate either species (Richards *et al.* 1993). However, intensive searching of the type localities for these species in 1994 revealed that *T. eungellensis* was still present in the Eungella region (Hero, pers. comm.).

## NEW SOUTH WALES

In 1991, the *Endangered Fauna (Interim Protection) Act* was passed by the parliament of New South Wales and amended the *National Parks and Wildlife Act 1974*. This Act provided specific criteria for identifying the endangered fauna of New South Wales. It also recognized frogs as fauna for the first time. Previously, only mammals, birds and reptiles were recognized as fauna. The Act also provided for a Scientific Committee of three people, one from the National Parks and Wildlife Service, one from the Australian Museum and one from the Ecological Society of Australia to assess the status of the fauna (Lunnéy and Ayers 1993). In 1992 the New South Wales National Parks and Wildlife Service, carrying out the work for the Scientific Committee, issued questionnaires to field herpetologists to gauge the

status of frog populations in the state. The participants in the survey were asked to forward information about changes in the distribution and population size of the frog species that they were studying, to evaluate the habitat of these frogs and any apparent threats to the species. This information formed the basis Schedule 12 of the Act, listing certain species as endangered under the categories of either "Threatened" or "Vulnerable and Rare".

Fifteen frog species were identified as being in serious decline and were included on Schedule 12. Four were listed as "Threatened" while 11 were classified as "Vulnerable and Rare" (Table 1). "Threatened" species were those deemed to be in serious decline and in danger of imminent extinction. "Vulnerable and Rare" species were so classified as their population numbers were seriously restricted by a limited geographic range, dwindling habitats or because of known ecological threats.

Table 1. Frog species listed on Schedule 12 of the *National Parks and Wildlife Service Act*, New South Wales.

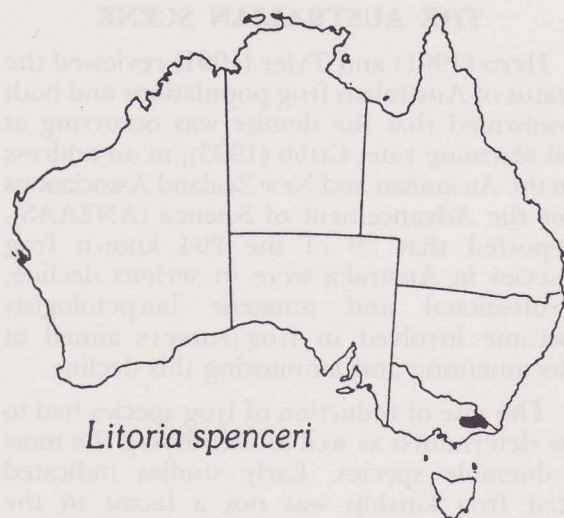
Threatened Species	
<i>Litoria aurea</i>	Green and Golden Bell Frog
<i>Litoria castanea</i>	
<i>Litoria raniformis</i>	Southern Bell Frog
<i>Litoria spenceri</i>	Spotted Tree Frog
Vulnerable and Rare Species	
<i>Litoria brevipalmata</i>	Green Thighed Tree Frog
<i>Litoria olongburensis</i>	
<i>Litoria pipera</i>	Speckled Tree Frog
<i>Litoria subglandulosa</i>	
<i>Assa darlingtoni</i>	Hip Pocket Frog
<i>Crimia tinnula</i>	Wallum Frog
<i>Heleioporus australiacus</i>	Giant Burrowing Frog
<i>Mixophyes fleayi</i>	
<i>Mixophyes balbus</i>	
<i>Mixophyes iteratus</i>	Giant Barred Frog
<i>Philoria kundagungan</i>	
<i>Philoria loveridgei</i>	Loveridge's Frog
<i>Philoria sphagnicolus</i>	Sphagnum Frog
<i>Pseudophryne australis</i>	Red Crowned Toadlet
<i>Pseudophryne corroboree</i>	Corroboree Frog

The four "Threatened" species were all tree frogs (family Hylidae). Three, namely *Litoria aurea*, *L. castanea* and *L. raniformis*, are closely related sibling species belonging to the *Litoria aurea* species complex (Cogger 1992). *Litoria aurea*, commonly known as the Green and Golden Bell Frog, had a distribution that extended along the coastal strip of New South Wales from Byron Bay down to the Victorian border, into the southern slopes and the Australian Capital Territory (Fig. 1). This distribution has shrunk considerably since the 1960s when it was regarded as common along



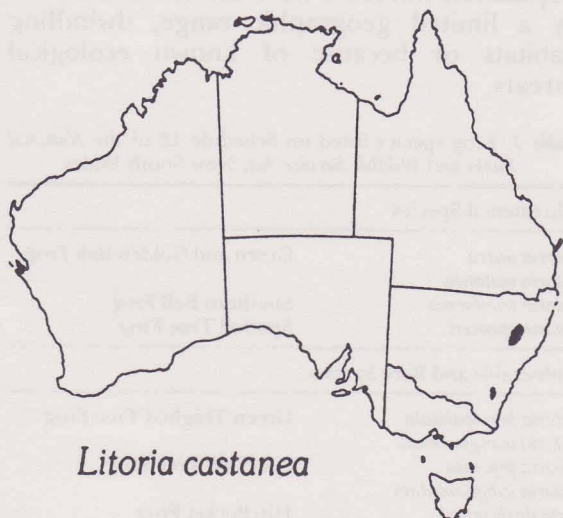
*Litoria aurea*

Fig. 1. Distribution range of *Litoria aurea* in New South Wales based on historical and current records (Cogger 1992).



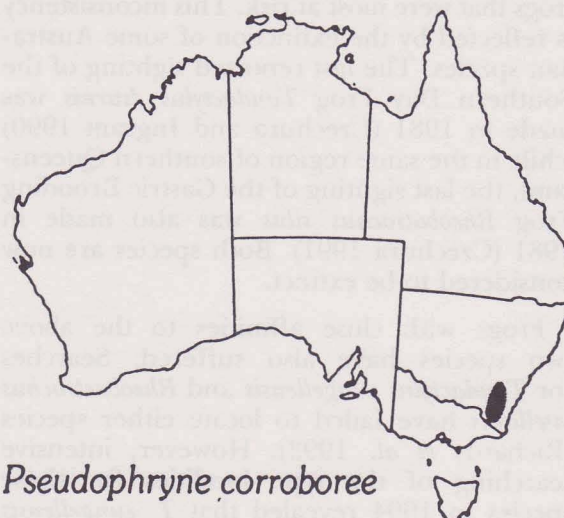
*Litoria spenceri*

Fig. 4. Distributional range of *Litoria spenceri* in New South Wales (Cogger 1992).



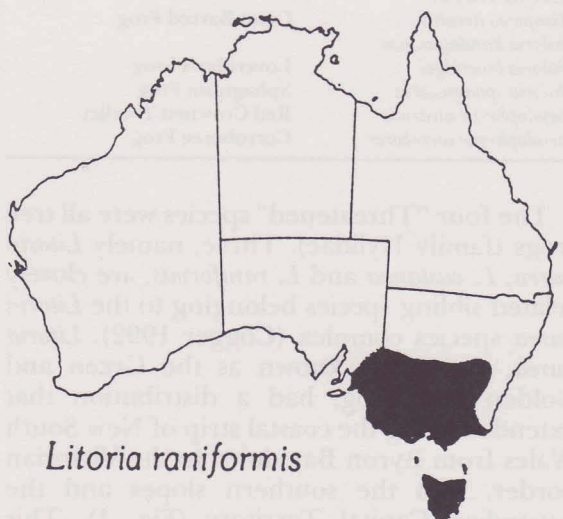
*Litoria castanea*

Fig. 2. Distributional range of *Litoria castanea* in New South Wales (Cogger 1992).



*Pseudophryne corroborree*

Fig. 5. Distributional range of *Pseudophryne corroborree* in New South Wales (Osborne 1989).



*Litoria raniformis*

Fig. 3. Distributional range of *Litoria raniformis* in New South Wales (Cogger 1992).



Fig. 6. *Litoria aurea* from Kurnell, New south Wales. Photograph taken in September 1992.

the New South Wales coast (Tyler 1991). Recent surveys by the New South Wales Frog and Tadpole Study Group Inc. have found that it no longer occurs on the south-west slopes or in the Australian Capital Territory. Its distribution along the coast is now patchy, with its largest populations in the Sydney Metropolitan Area and the Shoalhaven District (White 1995).

*Litoria castanea*, another Bell Frog, has an unusual distribution (Fig. 2). The species was known from two isolated populations, one in the Australian Capital Territory, the other in the New England district of northern New South Wales. The Australian Capital Territory population is now regarded as extinct (Osborne 1992) while Bell Frogs have not been seen in the New England region for a number of years. Dr Michael Mahony of Newcastle University will be undertaking an intensive search for the New England Bell Frogs over the next two years.

*Litoria raniformis*, the Southern Bell Frog, has a limited distribution in New South Wales. It is found in areas along the Murray River and its tributaries, but has a centre of distribution in Victoria and Tasmania where the species appears to be secure (Fig. 3).

The Spotted Tree Frog *Litoria spenceri* has a restricted mountain distribution (Fig. 4). It is confined to border ranges that form the northern part of the Victorian Alps and the southern part of the New South Wales Alps. In both states the Spotted Tree frog is regarded as a threatened species.

The majority of the species listed as "Vulnerable and Rare" are those with historically limited distributions. They are ecological specialists, capable of only surviving in a narrow range of habitats. Their specializations have made them vulnerable to habitat disturbance. The Corroboree Frog *Pseudophryne corroboree* inhabits sphagnum bogs and montane pasture of the Snowy Mountains and adjacent ranges (Fig. 5) which are frequently covered in snow in the winter. These small frogs take refuge in the centre of sphagnum clumps or in rotting logs beneath the blanket of snow (Tyler 1989). Increasing human activity in the highlands limits feeding and dispersal opportunities for these small frogs. In addition, habitat degradation due to grazing by introduced mammals such as cattle and pigs has further reduced the usable land area available for this species (Osborne 1989).

Studies by Osborne (1989) have revealed that this strikingly marked frog may in fact be two species; the defined species being confined

to the Snowy Mountains area, whereas the undescribed form occurs in the Brindabella and surrounding ranges along the western border of the Australian Capital Territory. The status of the undescribed form is a matter of concern since its numbers have been in marked decline (Osborne 1990).

#### CASE STUDY: THE GREEN AND GOLDEN BELL FROG

The Green and Golden Bell Frog (Fig. 6) is a species that has received a lot of public attention in New South Wales since its inclusion in Schedule 12. The reasons for its notoriety are rather varied and include:

1. an unexplained and dramatic decline of a once common New South Wales species.
2. the unusual ability of this species to colonize highly disturbed, artificial sites such as brick pits, disused industrial sites and mining areas (Fig. 7). The areas of colonization are not similar to the species' reported habitats of the 1960s (White 1995).
3. the ability to colonize disturbed sites has meant that the species has been encountered at times during proposed redevelopments of industrial land (Greer 1993; White 1993).

It is the third reason that has placed wildlife officials, local councils, property developers and conservation groups into opposing camps. But this may also be the reason that will offer the best chance for the recovery of the species.

In 1993 and 1994 three major property developments in Sydney have had to deal with the presence of Green and Golden Bell Frogs on their land: these were a warehouse complex at Greenacre; a residential housing estate at Rosebery; and the proposed site for the Olympic tennis complex at Homebush Bay. In each case the developer was obliged to engage consultants to prepare Faunal Impact Statements (FIS) to assess the likely impacts of their proposed work and to look for ways to ameliorate these impacts if they were adverse to the survival of the frogs. The FISs for all three sites have been publicly displayed as well as reviewed by independent biologists and the responses have been evaluated by wildlife officials. From these responses the formulation of a co-ordinated plan of management of the species has emerged. This plan recommended long-term studies on the species habitat requirements, the construction of new habitats as well as the possible re-introduction of the frogs into areas that they had previously inhabited.



Fig. 7. (a) State Brick Pit at Homebush Bay, New South Wales. The brick pit contains the largest known population of *Litoria aurea* in New South Wales. (b) Cox's Creek Reserve, Greenacre, New South Wales. A small remnant of *Melaleuca* woodland in the Sydney Metropolitan area that contains *Litoria aurea*. (c) State Super Site, Rosebery, New South Wales. A highly disturbed site that contains a genetically distinctive population (Colgan, pers. comm.) of *Litoria aurea*. (d) Coomonderry Swamp, Shoalhaven District, New South Wales. A large *Typha* and *Eleocharis* swamp that contains regularly breeding populations of *Litoria aurea*.

## A HYPOTHESIS FOR THE DECLINE

A multitude of reasons for the decline of amphibians have been proposed. They can be put into three categories:

1. Acidification of waterways and "acid rain" (e.g., Honneggar 1981; Pierce 1985; Freda 1986; Dunson *et al.* 1992).
2. Destruction of breeding and refuge sites (e.g., Honneggar 1981; Hayes and Jennings 1986, 1988; Enge and Marion 1986).
3. Pollution by heavy metals and pesticides (e.g., Clark and Hall 1985; Berger 1989; Tyler 1989).

All reasons relate to human-induced environmental disturbance. Frogs appear to be highly susceptible to disturbance at a number of stages in their life cycle. Duellman and Trueb (1986) found that the membranes surrounding frog eggs were highly absorptive to a number of water-borne substances, including toxic pollutants such as insecticides. Tadpoles were similarly vulnerable to the effects of contaminants in the water (e.g., Dial 1976; Ghate and Mulherlar 1980; Clark and Hall 1985). Even the adult frog, because of its soft permeable skin, is not safe from the effects of water and air pollution (e.g., Freda 1986; Freda and McDonald 1990). This sensitivity has allowed some ecologists to use changes in frog populations as a measure of the contamination of a habitat (e.g., Tyler *et al.* 1981).

In Australia, there has been a number of recent studies into the factors affecting frog survivorship, which have recently been reviewed by Ferraro and Burgin (1993a). While adult Australian frogs are typically less aquatic than their northern hemisphere counterparts, mating and breeding is still performed in water for most species (Tyler 1989). The demise of Australian species could be due to global pollution effects, such as increased ultra-violet light levels caused by the depletion of the ozone layer (Yoon 1994), more local effects such as the clearing of bushland (Thomson 1978) or an outbreak of viral disease (Speare *et al.* 1994).

The hypothesis that a virulent disease is responsible for the decline of frog species along the eastern seaboard of Australia has gained impetus with the discovery of a pathological virus in moribund specimens of *Litoria nannotis*, *L. rheocolus* and *Taudactylus acutirostris* from northern Queensland. These species are regarded as being in decline and were being surveyed at the time to determine their population status (Trenerry *et al.* 1994).

This virus has also been detected in a Myobatrachid frog *Limnodynastes ornatus* (Speare and Smith 1992). The virus is reported to cause "dysfunction of the nervous system" as well as lead to necrosis in many internal organs including the liver, spleen and kidneys (Trenerry *et al.* 1994).

The pattern of frog decline in Queensland is also suggestive of the involvement of a pathogen. Changes to frog populations were reported in southern Queensland in the late 1970s (Czechura and Ingram 1990). These were followed by reports of declines in central Queensland in 1980 (McDonald 1990) and north Queensland in the mid-1980s (Richards *et al.* 1993). Thus there is a progressive south-to-north geographic trend in declines (Ingram and McDonald 1993).

Other features of the decline support this argument. If the main cause of frog decline was habitat destruction, frog species that occur in protected environments such as national parks, should be spared. The Stream Frog *Rheobatrachus vitellinus* and the Eungella Torrent Frog *Taudactylus eungellensis* are in drastic decline. The Stream Frog may already be extinct. Both have restricted ranges that are almost completely taken in by the boundaries of the Eungella National Park near Mackay in north Queensland (Tyler 1992). This area has been relatively free from human disturbance, other than recreational use, for a number of years.

If the proposed virus is the major cause of frog declines in Queensland it still needs to be resolved why this disease is so debilitating now. The virus, described as being similar to the "Bohle Iridovirus" (Trenerry *et al.* 1994) is known from many frog species, including those not in decline. In fact, it appears as though this virus is widespread among frogs, both within and outside of Australia. Its current prevalence and pathogenicity in Queensland suggest that other factors are implicated in its outbreak.

With many other Australian frogs in decline, there appears to be strong human involvement. The disappearance of the Gastric Brooding Frog *Rheobatrachus silus* coincides with logging and gold mining activity upstream of its main habitat (Tyler and Davies 1985). Dam building and flooding lowlands (Plowman 1991), mining activity (Nichols and Bamford 1985) and urbanization (Ferraro and Burgin 1993b) have been cited as factors in reducing frog populations. In these examples, the reductions result not from the destruction of the animals directly but of a vital part of their habitat.

One trend in the pattern of frog disappearance is that the species that occur in moister habitats seem to be the most vulnerable. Richards *et al.* (1993) reported the decline of a number of rainforest species from north Queensland and failed to locate either the Nyakala Frog *Litoria nyakalensis* or the Tinkling Frog *Taudactylus rheophilus*. In addition, they reported a major range reduction for four other rainforest species. In particular, southern upland rainforest regions have experienced the greatest loss of frog populations. No direct causal agent could be found but the fragmentation of the rainforest seemed to be implicated. Human populations are concentrated in the more mesic areas of Australia. Direct and indirect disturbance of native species is paramount in these areas.

### HUMAN RESPONSE TO AMPHIBIAN DECLINES

A co-ordinated response to a global problem takes time, money and effort. The impetus to begin such a response came strongly from the First World Congress of Herpetology. The need to assess and deal with amphibian declines in the global context was formulated in 1990. Representative scientists from many parts of the world met at a National Science Foundation workshop in California. Possible strategies were tabulated and the Declining Amphibian Task Force was formed (Tyler 1993a). The task force established networks among the scientific herpetological communities to quantify the extent of declines, assess their causes and recommend responses. At present there are over 100 member countries contributing to the task force (Tyler 1993a).

The Australian task force's first action was to survey field naturalists, environmental organizations and research workers regarding the extent of frog declines. It sought to determine which species were in decline, how much information was available and the security of the populations in the long term. The University of Adelaide co-ordinated the survey under the banner of "Frogwatch". The surveyers quickly discovered that much of the information was being provided by amateur biologists. It was recognized that these people spend more time in the field and were noting population changes (Tyler 1993b).

The formulation of the Frog Action Plan (Tyler 1993a) revealed glaring gaps in our knowledge of the biology of a number of frog species. Taxonomic problems (such as for the northern and southern forms of the Corroboree Frog) have interfered with data

collation. Not all areas of Australia have been adequately surveyed and frog populations have yet to be assessed equally across the country. Information about species and numbers is especially inadequate for areas such as the Kimberleys, the western portion of the Gulf of Carpentaria, Barkly Tablelands and central deserts. A great deal of research needs to be done if the plan is to be of any use. This work will require funding. Government and private sponsorship of the research is essential. Equally important is that information about the plight of frogs reaches the attention of the general public.

### THE FUTURE

The sensitivity of frogs to environmental disturbances has seen some writers refer to these animals as "the world's canary" (Pechmann and Wilbur 1994). Frog declines are symptomatic of environmental vandalism and warn that a change in our use of this planet is necessary. Such changes would include:

1. a change in attitude to halt habitat destruction;
2. a reduction in the activities that reduce global biodiversity;
3. a reduction in the use of commercial compounds, such as pesticides, fertilizers and petro-chemicals;
4. a change in methods of waste disposal;
5. the initiation of detailed biological studies into the survival requirements of frogs;
6. an increase in public awareness of the plight of declining species and the implications for humanity; and
7. an increase in research to restore habitats and the possible translocation of doomed species.

Forums, such as the Second World Congress of Herpetology held in Adelaide in December 1993 and January 1994, and the Royal Zoological Society of New South Wales' publications on conserving biodiversity (Lunney 1992), Herpetology in Australia (Lunney and Ayers 1993) and conserving the fauna of western New South Wales (Lunney *et al.* 1994), is an essential part of this process. The Frog Action Plan is not yet completed but recommendations from it are already being incorporated into research proposals. The impetus exists to stop our frogs from disappearing.

## ACKNOWLEDGEMENTS

Special thanks are owed to the many people engaged in frog research around Australia. In particular, the many amateur herpetological groups who are compiling field data that will be critical in the long-term management of frog species deserve commendation. In this category, the New South Wales Frog and Tadpole Study Group Inc. deserves special mention. I would also like to thank Alison Matthews for making critical comments to the manuscript and Dan Lunney for his encouragement with this paper and his efforts towards the realization of active, meaningful zoology.

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